Member, Office of Technology Assessment Advisory Panel on Communications Systems for an Information Age, 1986–1988.

Member, Regional Telecommunications Planning Advisory Committee, City of Cincinnati, 1985.

Member, Office of Technology Assessment Advisory Panel on Intellectual Property Rights in an Age of Electronics and Information, 1984–1985.

Expert, World Intellectual Property Organization/UNESCO Meeting on Unauthorized Private Copying of Recordings, Broadcasts, and Printed Matter, 1984.

Listed in *Who's Who in America*, 1982–1983, 1984–1985, 1986–1987, 1988–1989, 1990–1991.

Member, Editorial Board, *Southern Economic Journal*, 1979–1981.

Member, Task Force on National Telecommunications Policy Making, Aspen Institute Program on Communications and Society, 1977.

Brookings Economic Policy Fellow, 1971–1972.

Member, Technical Advisory Committee on Business Development, Model City Program, City of Houston, 1969–1971.

Wilson University Fellow, 1959–1961.

Overbrook Fellow, 1958–1959.

Beta Gamma Sigma, 1958.

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Witness, Subcommittee on Intellectual Property and Judicial Administration, Committee on the Judiciary, U.S. House of Representatives, 1991. Prepared statement and testimony appear in *Intellectual Property and International Issues*, 102nd Congress, 1st Session, forthcoming.

Witness, Subcommittee on Telecommunications and Finance, Committee on Energy and Commerce, U.S. House of Representatives, 1990. Prepared statement and testimony appear in *Cable Television Regulation (Part 2)*, 101st Congress, 2nd Session.

Witness, Subcommittee on Telecommunications, Consumer Protection, and Finance, Committee on Energy and Commerce, U.S. House of Representatives, 1983. Prepared statement and testimony appear in *Options for Cable Legislation*, 98th Congress, 1st Session.

Witness, Subcommittee on Communications, Committee on Commerce, Science, and Transportation, U.S. Senate, 1982. Prepared statement and testimony appear in *Cable Television Regulation*, 97th Congress, 2nd Session.

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Witness, Subcommittee on General Oversight and Minority Enterprise, Committee on Small Business, U.S. House of Representatives, 1980. Prepared statement and testimony appear in *Media Concentration (Part 1)*, 96th Congress, 2nd Session.

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Witness, Subcommittee on Communications, Committee on Interstate and Foreign Commerce, U.S. House of Representatives, 1976. Prepared statement and testimony appear in *Cable Television Regulation Oversight - Part 1*, 94th Congress, 2nd Session.

ROBERT J. LARNER — Vice President

Ph.D.	Economics, University of Wisconsin, 1968
M.A.	Economics, University of Wisconsin, 1967
B.A.	Economics, Georgetown University, 1964

Dr. Larner is a Vice President with responsibility in the areas of industrial organization, antitrust, and regulation. His fields of specialization are price theory, industrial organization, the economics of antitrust and government regulation, and the economics of innovation.

He has performed or directed much of CRA's research in the area of science and technology policy in projects funded by the National Bureau of Standards, the Office of Technology Assessment, and the National Science Foundation. A common theme in many of these studies has been an analysis and quantitative estimation of the effects of government policy on competition, innovation, and productivity in technology-based industries.

Dr. Larner has assisted counsel in a large number of antitrust matters involving a range of issues — monopolization, mergers and acquisitions, price-fixing, vertical restraints, damages, and government regulation. He has also estimated damages and/or analyzed damages claims in other types of litigation. The industries or economic activities he has studied include:

- Telecommunications
- Semiconductors
- Computers and computer software
- COM recorders
- Photographic products and services
- Pharmaceuticals
- Chemicals
- Electrical equipment
- Appliances
- Garage door products
- Building products
- Highway materials
- Broadcast and cable television
- Local advertising media
- Electric power
- Natural gas
- Petroleum
- Uranium enrichment
- Ocean shipping
- Air transportation
- Rail transportation
- Health care
- Payment systems
- Soft drink bottling
- Brewing
- Baking
- Floral wire services
- Department stores
- Men's clothing
- Perfumes
- Glass containers
- Distribution of food
- Distribution of alcoholic beverages
- Fast foods service industry
- Distribution of automobiles
- Distribution of petroleum products
- Shopping centers
- Home textiles and furnishings

- Mobile homes
- Water purification equipment
- Cement
- Industrial sands
- Iron ore
- Metal fabrication
- Steel tubing
- Ball bearings
- Weapons systems

PREVIOUS EXPERIENCE

Adjunct Associate Professor of Economics, Boston College, Spring Semester 1991.

Assistant Professor of Economics, Brandeis University, 1968–1976. Dr. Larner taught courses in price theory, industrial organization, the economics of regulation, principles of economics, and the history of economic thought.

Staff Economist and later Chief of the Division of Industry Analysis, Bureau of Economics, Federal Trade Commission, 1971–1973. As Chief of the Division, Dr. Larner had responsibility for supervising the unit's research projects, which were primarily industry studies and studies of the economic effects of trade practices.

Assistant Professor of Economics, Harvard University, Summer 1970.

Business Economist, U.S. Department of Commerce, 1964. Dr. Larner participated in preparing the Department's publication, *Survey of Current Business*.

TESTIMONY

Dr. Larner gave testimony before the Senate Antitrust and Monopoly Subcommittee in support of the Competition Improvements Act, Senate bill #S. 2028, February 4, 1976.

Mead Corporation v. Occidental Petroleum Corporation, 1978 (consulted to Wald, Harkrader & Ross representing Occidental and testified in behalf of Occidental).

Frank Saltz & Sons v. Hart Schaffner & Marx, 1984 (testified in behalf of plaintiff).

Philadelphia Fast Foods, Inc. v. Popeyes Famous Fried Chicken, Inc. et al., 1985 (testified in behalf of plaintiff regarding damages).

Telectron, Inc. v. Overhead Door Corporation, 1985 (deposition testimony in behalf of defendant).

Sun–Drop Bottling Company, Incorporated, et al. v. Pepsi–Cola Bottling Company of Charlotte, Inc., 1986 (deposition testimony in behalf of defendant).

Testimony before the Oklahoma Corporation Commission in behalf of TelaMarketing Communications of America regarding telephone access charges, 1986.

Testimony before the U.S. Department of Justice, Drug Enforcement Administration in behalf of Ciba–Geigy in the matter of Methylphenidate Quotas for 1986, 1986.

J.F. Feeser, Inc. et al. v. Serv-A-Portion, Inc. et al., 1988 (deposition testimony in behalf of plaintiff).

Computer Associates International, Inc. v. Altai, Inc., 1990 (deposition and trial testimony in behalf of plaintiff regarding damages).

Symbol Technologies, Inc. v. Metrologic Instruments, Inc., 1991 (deposition testimony in behalf of plaintiff regarding damages).

AFFIDAVITS

J. F. Feeser, Inc. et al. v. Serv-A-Portion, Inc. et al., 1986, 1988 (2).

In Re Minolta Camera Products Antitrust Litigation, 1986; retained by both sides to evaluate proposed settlement between the states and Minolta.

Purofied Down Products Corporation v. Pillowtex Corporation, et al., 1987 (in behalf of defendant); evaluated competitive effects of proposed acquisition.

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Miller Brewing Company v. Silver Bros. Co., Inc., et al., 1989.

In Re Panasonic Consumer Electronics Products Antitrust Litigation, 1989; retained by both sides to evaluate proposed settlement between the states and Panasonic.

Federal Trade Commission v. Imo Industries, Inc. and Optic–Electronic Corporation, 1989 (in behalf of respondents); evaluated competitive effects of proposed acquisition.

O'Brien International, Inc. v. H.O. Sports, Inc., et al., 1991, (in behalf of plaintiff); estimated damages from trademark infringement.

PROFESSIONAL ACTIVITIES AND HONORS

American Economic Association.

Journal of Industrial Economics, Associate Editor, 1977–1987.

National Science Foundation Graduate Dissertation Fellowship, 1966 to 1968.

SELECTED PUBLICATIONS AND PRESENTATIONS

Economics and Antitrust Policy. Coeditor with James W. Meehan, Jr. Quorum Books, 1989.

"Vertical Restraints: Per se or Rule of Reason?" In *Economics and Antitrust Policy*, 1989.

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"Vertical Price Restraints: Per Se or Rule of Reasons?" Paper prepared for the Economics Committee of the Section of Antitrust Law of the American Bar Association, March 9, 1987.

Discussant on the topic of the Per Se Rule on Resale Price Maintenance. Annual Meeting of Section of Antitrust Law, American Bar Association, New Orleans, August 1981.

"A Proposed Rule of Reason for Vertical Restraints on Competition." With James W. Meehan, Jr. *The Antitrust Bulletin* (Summer 1981): 195–225.

"Economic Effects of Territorial Restrictions in the Soft Drink Industry." *The Antitrust Bulletin* (Spring 1977): 145–156.

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"Separation of Ownership and Control and Its Implications for the Behavior of the Firm." Ph.D. dissertation, University of Wisconsin, 1968.

"Ownership and Control in the 200 Largest Nonfinancial Corporations, 1929 and 1963." *American Economic Review* (September 1966).

JANE MURDOCH — Senior Associate

Ph.D.	Economics, UCLA
M.A.	Economics, UCLA
B. Comm.	Queen's University (Honors)

Jane Murdoch is a Senior Associate in CRA's Economic Litigation Program. Her areas of expertise include industrial organization and public finance. Some examples of her CRA project experience include:

- An analysis of pricing and marketing practices in a price-fixing investigation of a national food producer;
- A study of measures of geographic and product market definition relating to the merger of electric utility companies; and
- An evaluation of the business relation between a major provider of cellular telephone services and its agent and an assessment of damages relating to an alleged breach of contract.
- Analysis of price movements of the products within an aerospace supplier's product line over a four-year period;
- Research of the likely competitive effects of relaxing regulations governing the provision of cellular telephone service by Regional Bell Operating Companies.

PROFESSIONAL EXPERIENCE

Pepperdine University

Instructor, Winter 1989. Taught upper-class econometrics course.

ICF Consulting Associates

Intern, Summer 1988. Participated in an empirical study of the effect of mergers in hospital markets and a project examining the effects of proposed price cap regulation in the telecommunications industry.

UCLA

Research assistant, 1988 and 1985 – 1986. Worked on empirical studies of the effects of Individual Retirement Accounts on households' saving behavior and households' demand for automobiles, respectively.

Teaching assistant, 1985 – 1986, 1986 – 1987, and 1988 – 1989. Led discussion sections for introductory and intermediate microeconomics courses.

HONORS

- Earhart Foundation Fellowship, 1986 – 1987 and 1987 – 1988.
- Mefferd Fellowship, 1988 – 1989.

DISSERTATION

"Executive Compensation and Firm Performance: The Relationship Between Monitoring Difficulty and the Use of Incentive Contracts." Completed July 1991.

APPENDIX B

WHY CELLULAR CARRIERS REQUIRE ACCESS TO PCS SPECTRUM

Although cellular carriers have 25 MHz of spectrum in which to provide service to their customers, this will not be adequate to meet the growing needs of both current and new users of wireless communications services.

The attached studies -- conducted by CTIA and two outside consultants -- reveal a number of technical reasons why the cellular industry must have access to additional spectrum to both serve existing cellular customers and to have the opportunity to better serve the public by offering a range of new narrowband and broadband services that will complement existing cellular voice and low speed data services.

The capacity limitations described in the study can be summarized as follows:

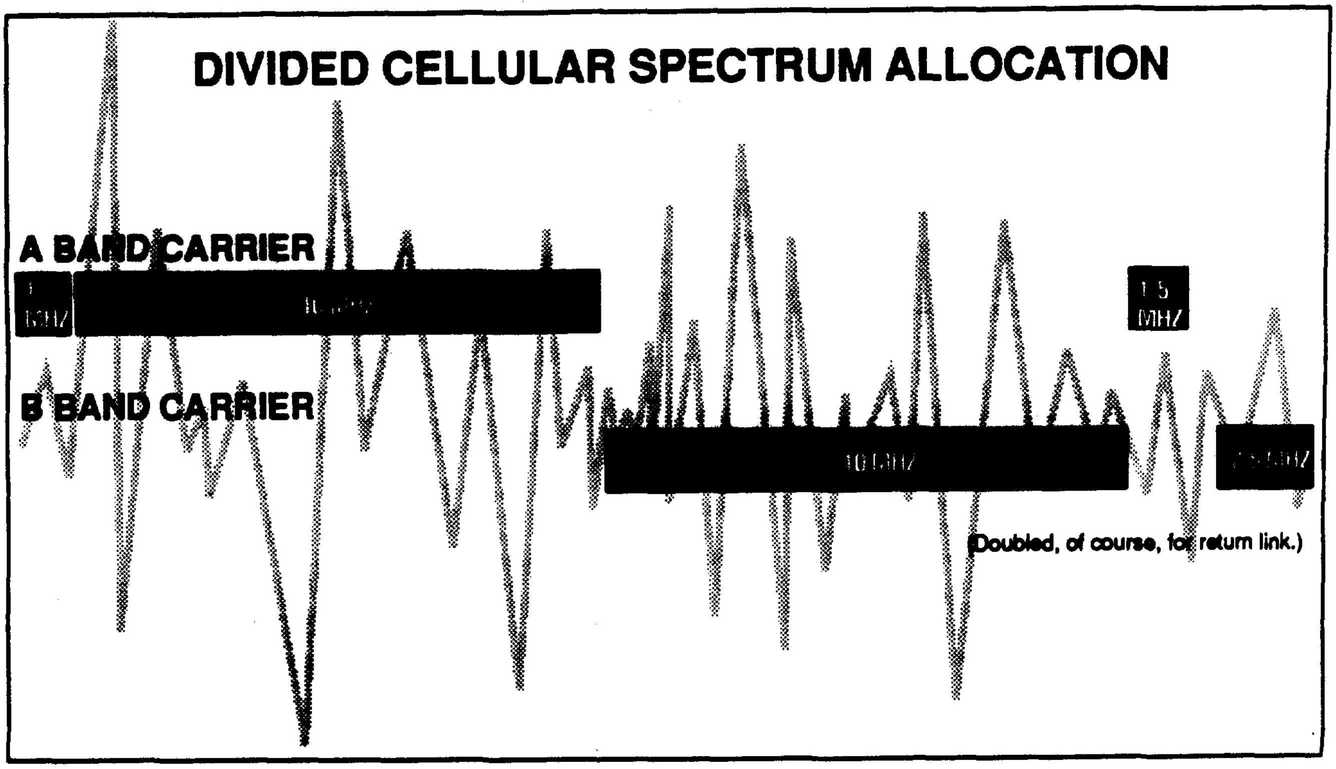
1. Meeting Obligations to Existing Analog Users. The first obligation of cellular carriers is to their current and growing base of customers using analog technology -- expected to number 18-20 million by the time that PCS services are launched. The public interest would not be served if cellular carriers abandoned their analog customers and rendered their equipment obsolete. Even by the year 2000, CTIA anticipates that 7.5 MHz of the existing 25 MHz allocation will be needed to serve existing analog users within their home areas and to permit these analog users to roam.

2. Ensuring Compatibility Among Digital Services. The ongoing transition to digital technology does not solve cellular's capacity problems, but actually exacerbates them. As different digital technologies are adopted, cellular carriers will need continued access to analog spectrum as a "universal language" or common interface to ensure ubiquitous service and roaming among non-compatible digital markets. CTIA projects that, ten years from now, 11.5 MHz of cellular's 25 MHz allocation will be needed to provide digital service and to ensure compatability among digital voice and low speed data services.

3. Providing New Broadband Services. The new digital services of the future, including video, multimedia and high speed data services, will be transmitted using broadband technologies that are technically incompatible with cellular's narrowband channelization and spectrum allocation. Cellular carriers' continuing commitments to analog and digital customers, outlined above, will leave only 6 MHz of their 25 MHz allocation for these new services. Without access to additional PCS spectrum, this capacity limitation effectively denies cellular carriers the opportunity to offer new broadband services to existing voice customers. More importantly, cellular customers are also denied the cost-effective option of having one service provider for both their voice and broadband data needs.

Capacity Limitations

The FCC grants two licenses to provide cellular service in a given geographical area, often referred to as the A band carrier and the B band carrier. Each carrier is allocated 25 MHz of spectrum. This 25 MHz allocation is divided into a 12.5 MHz forward link (from the base station to the subscriber unit) and a 12.5 MHz reverse link (from the subscriber unit to the base station). Although, both A band and B band carriers have equal access to spectrum, the actual allocations are split differently as illustrated below.



Currently both the A band and B band carrier use an analog radio technology called AMPS (Advanced Mobile Phone Service) which divides their spectrum into 416 channels, each with 30 KHz of bandwidth. Each of these channels can carry a single voice conversation at a time.

The cellular industry is transitioning to digital technology and has already developed a TDMA standard, known as IS-54 which permits three simultaneous voice conversations on a single 30 KHz channel. The industry is also in the process of developing another digital standard, based on CDMA technology, which aggregates channels together and permits multiple voice conversations over the aggregated bandwidth. There are two general types of CDMA technology, referred to as narrow band and wideband. Narrowband CDMA as advocated by Qualcomm aggregates 41.6 AMPS channels (10% of the available spectrum) into a 1.248 MHz channel. Wideband CDMA as advocated by SCS Mobilecom aggregates 333 channels into a channel of 10 MHz bandwidth.

There are two basic ways of increasing the capacity of a cellular system. One is to use more efficient modulation and multiple access technology to increase throughput per MHz of bandwidth and that is accomplished throughout the transition to digital technology. The second is to reduce cell size and thus reuse frequencies more efficiently. (PCS is based on using small, low powered, microcells with digital modulation technology.) However, there are limitations as to how small the cell can be. As cars move through cells at relatively high speeds, the software logic in the cellular switching has to be fast enough to hand off from cell to cell. Practical limits on cell size are in the order of a half mile radius.

Cellular carriers' capacity can be increased by shrinking cells and converting to digital radio technology. However, there are clearly practical limits to both techniques. There are finite, practical limits on throughput and handoff requirements for rapidly moving subscribers limits cell size. There is no right answer to the question, "How many subscribers can a cell handle?" but as a rough measure Don Schilling from SCS Mobilecom (now Interdigital Corp.) has indicated that with 8 kb/s voice encoding and 5000 feet cell radius, a cellular carrier could handle 1000 simultaneous voice conversations /sq. mile.

Once these practical limits are met, the service provider can only serve more users by degrading the quality of service to existing users (an unacceptable option) or obtaining more spectrum. Excluding a cellular provider from obtaining more spectrum penalizes a carrier that may have through good marketing, good customer service, low prices, etc. attracted a significant customer base.

Analog User Obligations

In some large cities, cellular service is reaching the limits of its capacity with penetration rates of 3% of the population. Currently, all subscriber units are analog. The cellular industry conversion to digital technology will take place over approximately ten years and for much of that time the number of subscribers using analog units will continue to grow. This growth combined with the need to allocate spectrum to digital cellular users and potential PCS digital subscribers can not be accommodated within the existing 25 MHz cellular allocation.

In order to illustrate this concern, CTIA has constructed an analysis which assumes a conservative cellular subscriber growth rate of 20% per year. With this growth, in five years cellular service penetration rates will be 6.0% of the population and in ten years 15%. This is consistent with most industry analysts who project cellular to reach a 10-20% penetration rate of the general population.

Clearly, not all of the new cellular subscriber units sold will be digital. Because the initial dual-mode digital units are either more expensive or heavier, analog units will continue to be sold. The analysis assumes that 50% of new units sold in year 5 are digital and in 10 years all new units sold are digital. It also assumes that 10% of the existing analog units are exchanged for new digital subscriber units every year.

The result is that in five years, 60% of all cellular subscriber units are still analog. Even after ten years 15% of all subscriber units are still analog. Table 1 illustrates that the total number of analog units continues to grow until year 6 and that the total number of analog subscribers does not drop below the current analog subscriber base until year 10. The implications are clear. Cellular's need to provide analog service will grow for some time before it begins to diminish as the industry transitions to digital cellular.

In year 6 cellular will have to support one third more analog subscribers than it does today. In year 10 the industry will still have to support 80% of the analog subscribers that it does today, representing an analog penetration rate of over 2% of the population. These subscribers still must be provided service under cellular carriers' common carrier obligations. If a 3% penetration rate today uses all 25 MHz of spectrum, then a 2% subscriber population would imply that 2/3 of the 25 MHz allocation would still have to be reserved for analog users.

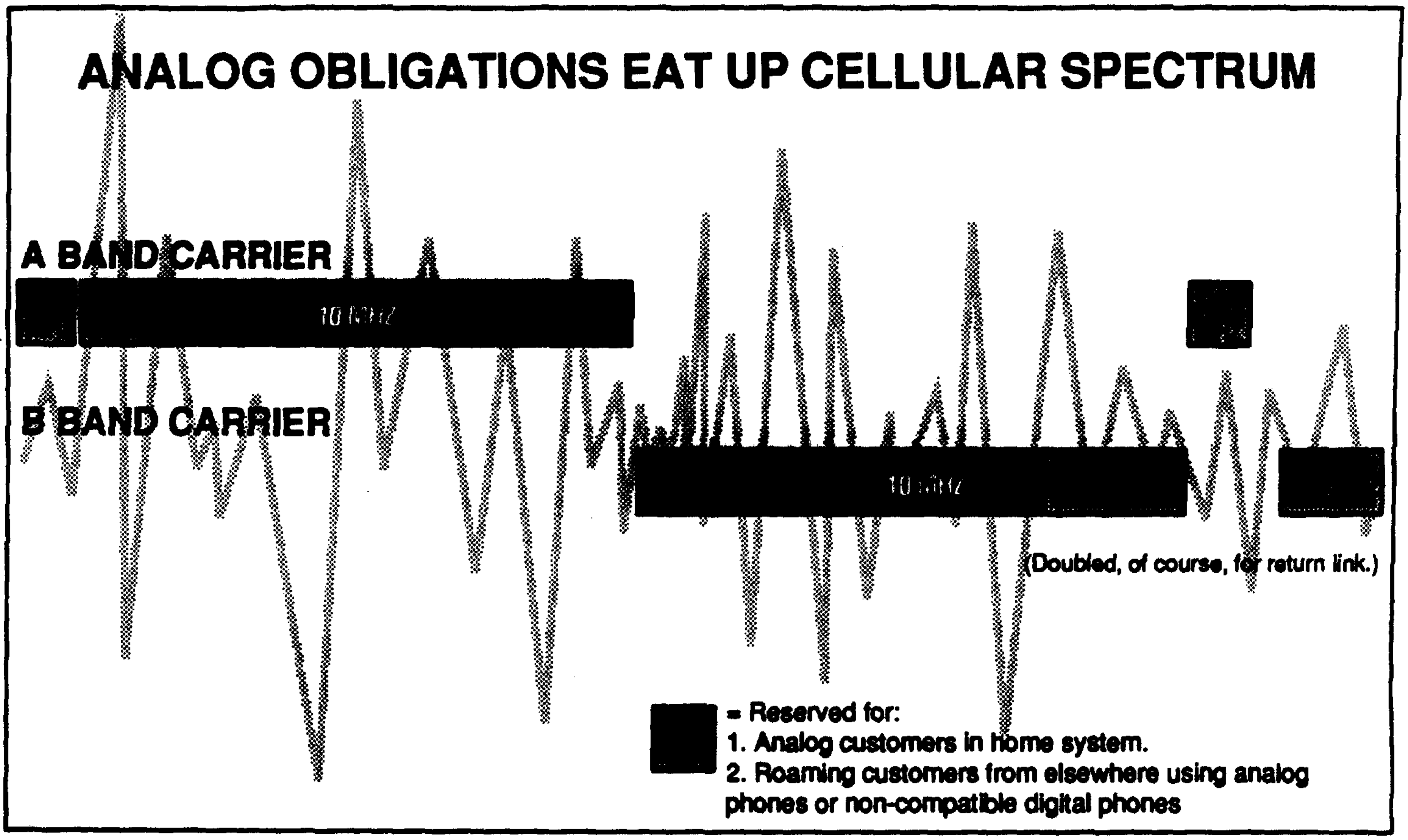
However, it is likely that the analog user of tomorrow will utilize less air time than the digital cellular user of tomorrow. There are no reliable estimates of the relative air time usage of analog vs. digital users. Based on some broad estimates, it is reasonable to assume that digital subscribers will use three times the amount of air time per month than do analog users. Under that assumption, 2/9 of the 25 MHz of spectrum would still need to be reserved for analog users in year 10. That means that even after transition to digital over 5 MHz of the cellular allocation will be needed to serve analog users.

However, the above analysis focuses only on subscribers in their home market. It does not take into account subscribers from other systems that require service, so-called roamers. If the roamer's home system has not converted to digital service, the roamer will be using an analog unit and will require analog service. Also if the roamer's home system is not using the same digital system as this city, e.g., CDMA vs. TDMA, the roamer will use his dual mode digital subscriber unit in the analog mode.

Currently roaming traffic is 10-15% of a home system's revenue and growing very rapidly. There may be several reasons for this, including higher penetration rates across the general population and the increased reliance on hand held portables by the mobile business traveler. Most of this roaming traffic will continue to be analog. The analog roamer will be a high air time user, with usage patterns more similar to a home digital user than a home analog user.

Based on the rapid growth of roamer traffic and the high air time use of these subscribers, it is very likely that a carrier will have to reserve as much of his existing spectrum for roamers as he does for home system analog users. The result is that cellular carriers serving large metropolitan areas will need to reserve 10 of their 25 MHz allocation for analog service even after a 10 year digital transition period. During the transition, analog spectrum needs will be even higher.

This 10 MHz of spectrum or 5 MHz on the forward and reverse link, is unavailable to the carrier as it allocates spectrum to digital cellular and PCS. (This reservation of spectrum for AMPS users has real public policy benefits. It provides a nationwide ubiquitous AMPS highway for all roamers and frequencies that can be used for disaster recovery organizations that have stockpiled analog units.) An illustration of the unavailable spectrum is illustrated below. The implications are clear. Cellular carriers will only have 7.5 MHz of clear spectrum on the forward and reverse links in which to provide digital cellular and PCS service.



Telocator and others have estimated that PCS services may require anywhere from a minimum of 18M MHz up to 72 MHz of new unshared spectrum per service provider. That equates to 9 MHz to 36 MHz of spectrum in each direction. Cellular carriers with only 7.5 MHz are at a disadvantage in providing PCS services. Indeed, given the need to provide digital cellular service and analog cellular service, there is not enough clear spectrum in the cellular band for broadband PCS services.

CHART A

Continuing Need To Serve Analog Customers
(Sample Markets)

YEAR	TOTAL SUBSCRIBERS	TOTAL ANALOG	TOTAL DIGITAL	% ANALOG
1992	300,000	300,000	0	100.00%
1993	360,000	324,000	36,000	90.00%
1994	432,000	348,600	83,400	80.69%
1995	518,400	371,580	146,820	71.68%
1996	622,080	390,078	232,002	62.71%
1997	746,496	400,395	346,101	53.64%
1998	895,795	397,750	498,045	44.40%
1999	1,074,954	375,975	698,979	34.98%
2000	1,289,945	327,129	962,816	25.36%
2001	1,547,935	241,020	1,306,915	15.57%
				SOURCE: CTIA

ASSUMPTIONS: *City of 10 million people, with 3% cellular subscriber penetration in 1992, growing by 20% per year; 10% of all new phones sold are digital in 1993, increasing by 10% each year, until all phones sold in 2001 are digital; each year 10% of analog phones are traded in for digital.*

Multimedia Communications

The PCS band appears particularly well suited for "multimedia communications," the transmission of video, high speed data and toll quality voice. These services are desired by existing cellular customers who presently use AMPS and eventually digital cellular for voice communications. Providing cellular carriers access to the PCS band, in areas where they currently provide cellular service, offers the cellular industry the opportunity to provide a full range of services to its customers.

One suggested way of providing multimedia services is with the use of broadband code division multiple access technology (B-CDMA). This technology spreads the transmitted data over wide bandwidths, thus permitting high data rates. The existing cellular allocations are 12.5 MHz wide on the forward and reverse links and the B-CDMA systems proposed are at least 10 MHz wide. It would be impossible for a cellular operator to allocate 10 MHz of his 12.5 MHz allocation, in a flash cut transition, in order to provide B-CDMA service in cleared spectrum. The operator would be eliminating 80% of its AMPS or narrowband TDMA channels and would create unacceptable levels of service for existing AMPS and digital cellular customers.

Cellular carriers would like the opportunity to provide multimedia services to their existing customers. However cellular carriers have only two choices for offering multimedia services. First they can offer these services in the PCS band. A dual mode phone would provide voice service in the cellular band and high speed data services in the PCS band. A second alternative, which is controversial and not well tested, is to overlay broadband CDMA technology on the existing AMPS and digital cellular spectrum.

CTIA asked Don Schilling, President of SCS Mobilecomm (now InterDigital Communications Corp.), and a noted expert in Broadband CDMA technology, to compare these two alternatives for providing multimedia services. (See attached report.) He focused on achievable data rates and capacity when B-CDMA is used as an overlay to narrowband AMPS users in the cellular band and when used as an overlay to point to point microwave users in the PCS frequency band. *

** CTIA is not endorsing the actual feasibility of B-CDMA overlay of cellular. However, since it has been identified as a possible alternative to permitting cellular companies access to PCS assigned spectrum, CTIA's analysis assumes its feasibility for these purposes.*

The results are dramatic. In general, a cellular carrier will be restricted to only one fourth of the capacity using B-CDMA as an overlay than would a PCS operator using B-CDMA as an overlay to point to point microwave users. This disadvantage suggests that cellular carriers will have a difficult time in providing multimedia services to their existing customers if they are unable to have access to additional spectrum.

The results are even more dramatic when practical concerns such as cell radius are taken into account. For example, Table 2.1 in the Schilling study indicates the number of users per square mile that can be supported by a cellular carrier vs. a PCS operator for similar data rates. Parts of that table are illustrated below:

USERS PER SQUARE MILE

Data Rates (kb/s)	Cellular Carrier	PCS Operator
32 (clear, uncoded voice)	64	2152
144 (ISDN data rates)	14	480
256 (stop motion video)	8	264
1544 (compressed video)	1	40

The conclusions are obvious. Cellular carriers can offer multimedia services as an overlay to AMPS users but can only provide service to a small fraction of the users they could serve if they had access to the PCS frequency band. Denying cellular carriers access to the PCS spectrum puts them at a competitive disadvantage with new PCS operators. It also denies cellular customers the ability to use one service provider for both their voice and high speed multimedia digital services.

Indoor Wireless Coverage

The cellular industry has expanded over the past 10 years from a phone service in automobiles to a pedestrian service using small hand held subscriber equipment. More than 60% of all new subscriber units sold are portable or transportable. The cellular industry's next evolution is to provide indoor service. Already, the cellular industry has taken large steps in that direction, using indoor microcells in train stations, sports arenas, shopping malls, airports, and most recently the underground service for the Washington D.C. metro system.

The ability to provide both indoor and outdoor service would be considerably enhanced if cellular companies had access to spectrum at 1800 MHz in their existing license areas. This is because of the frequency coordination difficulties in providing both indoor and outdoor service using microcells and because of the differences in propagation characteristics of radio signals at the cellular frequencies 800 MHz and the PCS frequencies 1800 MHz.

For example, if cellular carriers held licenses at 1800 MHz, they would have the option of using 1800 MHz indoors and 800 MHz outdoors, with little interference problems between the two services. Indeed a single subscriber unit provided by the cellular carrier could be dual mode and automatically switch from indoor service to outdoor service as the user walks outside a building.

In addition, radio signals at 1800 MHz attenuate faster than radio waves at 800 MHz. This creates better isolation between outdoor microcells and indoor microcells at 1800 MHz. A frequency planner can take advantage of this to insure less interference between indoor signals at 1800 MHz and outdoor systems.

CTIA has reviewed the technical literature on propagation at 800 MHz vs. 1800 MHz. Much of this literature is published in IEEE journals and many of the articles come from Europe or Canada where PCS service at 1800 MHz has already been licensed. In general 800 MHz signals propagate four times farther than 1800 MHz signals at the same power levels. Thus 800 MHz is a better frequency for outdoor macrocell use and in particular for serving the mobile automobile market.

However, the studies that compare indoor use at 1800 vs 800 MHz are much less conclusive. One frequency or the other may be more efficient in indoor use, depending on the building construction, the lay out of the offices in the building, and the number of users on each floor. Providing cellular companies the choice of frequencies allows a carrier to use the most efficient radio signal in providing service to a particular building or group of buildings. Conversely denying cellular carriers the ability to use 1800 MHz in their service territories limits a carriers' ability to provide the most efficient mix of coverages.

Research disclosed no published studies comparing the signal strength on the street from indoor microcells operating at 1800 MHz and at 800 MHz. To test the assumption that indoor microcells at 1800 MHz create less interference outside the building, CTIA asked the consulting firm of LCC, a well known frequency planning firm, to run some test experiments. Their results are attached. They indicate that at 1800 MHz there is a 3 to 6 DB greater loss of signal through building walls at 1850 MHz than there is at 900 MHz. A service provider can achieve better isolation between indoor and outdoor microcells when operating at the higher PCS frequencies.

From a consumer point of view, this means that denying cellular carriers PCS licenses at 1800 MHz in areas where they currently provide cellular service is to make it much more difficult for a single service provider to offer both indoor and cellular like outdoor wireless service.

COMPARISON OF BROADBAND CDMA IN THE CELLULAR AND PERSONAL COMMUNICATION SERVICES BAND

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